US008235909B2

(12) **United States Patent**
Barthe et al.

(10) **Patent No.: US 8,235,909 B2**
(45) **Date of Patent: Aug. 7, 2012**

(54) **METHOD AND SYSTEM FOR CONTROLLED SCANNING, IMAGING AND/OR THERAPY**

(75) Inventors: **Peter G. Barthe**, Phoenix, AZ (US); **Michael H. Slayton**, Tempe, AZ (US)

(73) Assignee: **Guided Therapy Systems, L.L.C.**, Mesa, AZ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 2079 days.

(21) Appl. No.: **11/126,760**

(22) Filed: **May 11, 2005**

(65) **Prior Publication Data**

US 2005/0256406 A1 Nov. 17, 2005

Related U.S. Application Data

(60) Provisional application No. 60/570,145, filed on May 12, 2004.

(51) **Int. Cl.**
A61B 8/14 (2006.01)

(52) **U.S. Cl.** **600/463**; 606/130

(58) **Field of Classification Search** 600/407, 600/411, 424–427, 437, 439, 443–446, 459, 600/461–463; 606/130; 128/916
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,913,386 A 10/1975 Saglio
3,965,455 A 6/1976 Hurwitz
3,992,925 A 11/1976 Perilhou
4,039,312 A 8/1977 Patru
4,059,098 A 11/1977 Murdock
4,101,795 A 7/1978 Fukumoto
4,213,344 A 7/1980 Rose
4,276,491 A 6/1981 Daniel
4,315,514 A 2/1982 Drewes et al.
4,325,381 A 4/1982 Glenn
4,343,301 A 8/1982 Indech

(Continued)

FOREIGN PATENT DOCUMENTS

DE 4029175 3/1992

(Continued)

OTHER PUBLICATIONS

Notice of Allowance, U.S. Appl. No. 11/163,177; mailed Oct. 9, 2008.
Notice of Allowance, U.S. Appl. No. 10/950,122; mailed Dec. 30, 2008.
Notice of Allowance, U.S. Appl. No. 11/163,155; mailed Jan. 30, 2009.
Notice of Allowance, U.S. Appl. No. 11/380,161; mailed Mar. 30, 2009.

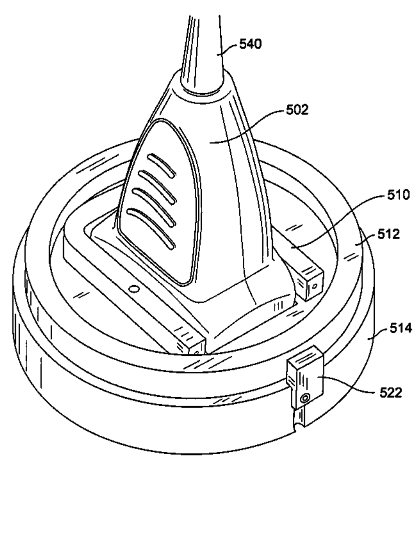
(Continued)

Primary Examiner — Brian Casler
Assistant Examiner — Saurel J Selkin
(74) *Attorney, Agent, or Firm* — Snell & Wilmer, L.L.P.

(57) **ABSTRACT**

A method and system for three dimensional scanning, imaging and/or therapy are provided. In accordance with one aspect, an exemplary method and system are configured to facilitate controlled scanning within one-degree of freedom. For example, an exemplary method and system can enable multiple two-dimensional image planes to be collected in a manner to provide an accurate and computationally efficient three-dimensional image reconstruction while providing the user with a user-friendly mechanism for acquiring three-dimensional images. In accordance with an exemplary embodiment, an exemplary scanning and imaging system comprises an imaging probe, a control system, a positioning system and a display system. In accordance with an exemplary embodiment, the positioning system comprises a guide assembly and a position sensing system. The guide assembly is configured to provide pure rectilinear or rotational motion of the probe during scanning operation while the position sensing system is configured to detect the direction and position of the probe during scanning.

24 Claims, 7 Drawing Sheets



U.S. PATENT DOCUMENTS

4,372,296	A		2/1983	Fahim	
4,381,007	A		4/1983	Doss	
4,381,787	A		5/1983	Hottinger	
4,397,314	A		8/1983	Vaguine	
4,409,839	A		10/1983	Tanezer	
4,441,486	A		4/1984	Pounds	
4,452,084	A		6/1984	Taenzer	
4,484,569	A		11/1984	Driller	
4,513,749	A		4/1985	Kino et al.	
4,527,550	A		7/1985	Ruggera et al.	
4,528,979	A		7/1985	Marchenko	
4,567,895	A		2/1986	Putzke	
4,586,512	A		5/1986	Do-Huu et al.	
4,601,296	A		7/1986	Yerushalmi	
4,646,756	A		3/1987	Watmough	
4,663,358	A		5/1987	Hyon	
4,668,516	A		5/1987	Duraffourd et al.	
4,697,588	A		10/1987	Reichenberger	
4,757,820	A		7/1988	Itoh	
4,807,633	A		2/1989	Fry	
4,858,613	A		8/1989	Fry et al.	
4,860,732	A		8/1989	Hasegawa et al.	
4,865,041	A		9/1989	Hassler	
4,865,042	A		9/1989	Umemura	
4,867,169	A		9/1989	Machida	
4,874,562	A		10/1989	Hyon	
4,875,487	A		10/1989	Seppi	
4,893,624	A		1/1990	Lele	
4,896,673	A		1/1990	Rose	
4,917,096	A		4/1990	Englehart et al.	
4,938,216	A		7/1990	Lele	
4,938,217	A		7/1990	Lele	
4,947,046	A		8/1990	Kawabata et al.	
4,951,653	A		8/1990	Fry et al.	
4,955,365	A		9/1990	Fry et al.	
4,958,626	A		9/1990	Nambu	
4,976,709	A		12/1990	Sand	
4,979,501	A		12/1990	Valchanov	
5,012,797	A		5/1991	Liang	
5,036,855	A		8/1991	Fry	
5,054,310	A		10/1991	Flynn	
5,054,470	A		10/1991	Sanghvi et al.	
5,115,814	A		5/1992	Griffith	
5,117,832	A		6/1992	Sanghvi et al.	
5,123,418	A		6/1992	Saurel	
5,143,063	A		9/1992	Fellner	
5,143,074	A		9/1992	Dory	
5,150,711	A		9/1992	Dory	
5,150,714	A		9/1992	Green	
5,156,144	A		10/1992	Iwasaki et al.	
5,158,536	A		10/1992	Sekins	
5,163,421	A		11/1992	Bernstein et al.	
5,191,880	A		3/1993	McLeod	
5,209,720	A		5/1993	Unger	
5,224,467	A		7/1993	Oku	
5,230,334	A		7/1993	Klopotek	
5,230,338	A		7/1993	Allen et al.	
5,265,614	A		11/1993	Hayakawa	
5,267,985	A		12/1993	Shimada et al.	
5,269,297	A		12/1993	Weng et al.	
5,282,797	A		2/1994	Chess	
5,295,484	A		3/1994	Marcus	
5,304,169	A		4/1994	Sand	
5,321,520	A		6/1994	Inga et al.	
5,360,268	A		11/1994	Hayashi	
5,370,121	A		12/1994	Reichenberger et al.	
5,371,483	A		12/1994	Bhardwaj	
5,380,280	A		1/1995	Peterson	
5,419,327	A		5/1995	Rohwedder et al.	
5,435,311	A		7/1995	Umemura	
5,458,596	A		10/1995	Lax	
5,460,595	A		10/1995	Hall et al.	
5,471,988	A		12/1995	Fujio et al.	
5,487,388	A	*	1/1996	Rello et al.	600/445
5,492,126	A		2/1996	Hennige et al.	
5,496,256	A		3/1996	Bock	
5,501,655	A		3/1996	Rolt et al.	
5,503,320	A		4/1996	Webster et al.	
5,507,790	A		4/1996	Weiss	
5,520,188	A		5/1996	Hennige et al.	
5,522,869	A		6/1996	Burdette	
5,524,620	A		6/1996	Rosenchein	
5,524,624	A		6/1996	Tepper	
5,526,812	A		6/1996	Dumoulin et al.	
5,526,814	A		6/1996	Cline et al.	
5,526,815	A		6/1996	Granz et al.	
5,540,235	A		7/1996	Wilson	
5,558,092	A		9/1996	Unger	
5,560,362	A		10/1996	Sliwa et al.	
5,575,291	A		11/1996	Hayakawa	
5,575,807	A		11/1996	Faller	
5,577,502	A	*	11/1996	Darrow et al.	600/426
5,577,991	A		11/1996	Akui et al.	
5,580,575	A		12/1996	Unger et al.	
5,601,526	A		2/1997	Chapelon et al.	
5,603,323	A		2/1997	Pflugrath et al.	
5,609,562	A		3/1997	Kaali	
5,615,091	A		3/1997	Palatnik	
5,617,858	A		4/1997	Taverna et al.	
5,618,275	A		4/1997	Bock	
5,620,479	A		4/1997	Diederich	
5,638,819	A		6/1997	Manwaring et al.	
5,647,373	A		7/1997	Paltieli	
5,655,538	A		8/1997	Lorraine	
5,657,760	A		8/1997	Ying	
5,658,328	A		8/1997	Johnson	
5,660,836	A		8/1997	Knowlton	
5,665,053	A		9/1997	Jacobs	
5,676,692	A		10/1997	Sanghvi et al.	
5,685,820	A		11/1997	Riek et al.	
5,690,608	A		11/1997	Watanabe	
5,694,936	A		12/1997	Fujimoto	
5,697,897	A		12/1997	Buchholtz	
5,701,900	A		12/1997	Shehada et al.	
5,715,823	A		2/1998	Wood et al.	
5,720,287	A		2/1998	Chapelon et al.	
5,722,411	A		3/1998	Suzuki	
5,727,554	A		3/1998	Kalend et al.	
5,735,280	A		4/1998	Sherman et al.	
5,743,863	A		4/1998	Chapelon	
5,746,005	A	*	5/1998	Steinberg	33/1 PT
5,748,767	A		5/1998	Raab	
5,749,364	A		5/1998	Sliwa et al.	
5,755,228	A	*	5/1998	Wilson et al.	600/459
5,755,753	A		5/1998	Knowlton	
5,762,066	A		6/1998	Law et al.	
5,769,790	A		6/1998	Watkins	
5,795,297	A	*	8/1998	Daigle	600/447
5,795,311	A		8/1998	Wess	
5,810,888	A		9/1998	Fenn	
5,817,013	A		10/1998	Ginn et al.	
5,817,021	A		10/1998	Reichenberger	
5,820,564	A		10/1998	Slayton et al.	
5,823,962	A		10/1998	Schaetzle	
5,827,204	A		10/1998	Grandia et al.	
5,840,032	A		11/1998	Hatfield et al.	
5,844,140	A		12/1998	Seale	
5,853,367	A		12/1998	Chalek et al.	
5,869,751	A		2/1999	Bonin	
5,871,524	A		2/1999	Knowlton	
5,873,902	A		2/1999	Sanghvi et al.	
5,879,303	A		3/1999	Averkiou et al.	
5,882,557	A		3/1999	Hayakawa	
5,891,034	A		4/1999	Bucholz	
5,904,659	A		5/1999	Duarte et al.	
5,919,219	A		7/1999	Knowlton	
5,924,989	A	*	7/1999	Polz	600/443
5,928,169	A		7/1999	Schatzle et al.	
5,931,805	A		8/1999	Brisken	
5,938,606	A	*	8/1999	Bonnefous	600/437
5,938,612	A		8/1999	Kline-Schoder	
5,948,011	A		9/1999	Knowlton	
5,957,844	A	*	9/1999	Dekel et al.	600/439
5,957,882	A		9/1999	Nita et al.	
5,967,980	A	*	10/1999	Ferre et al.	600/424
5,968,034	A		10/1999	Fulmer	
5,971,949	A		10/1999	Levin et al.	

5,984,882 A 11/1999 Rosenchein et al.
5,997,471 A 12/1999 Gumb et al.
5,997,497 A 12/1999 Nita et al.
6,004,262 A 12/1999 Putz et al.
6,007,499 A 12/1999 Martin et al.
6,036,646 A * 3/2000 Barthe et al. 600/459
6,039,048 A * 3/2000 Silberg 128/898
6,042,556 A 3/2000 Beach et al.
6,049,159 A 4/2000 Barthe et al.
6,050,943 A * 4/2000 Slayton et al. 600/439
6,059,727 A 5/2000 Fowlkes
6,071,239 A 6/2000 Cribbs et al.
6,080,108 A * 6/2000 Dunham 600/459
6,086,535 A 7/2000 Ishibashi
6,086,580 A 7/2000 Mordon et al.
6,090,054 A 7/2000 Tagishi et al.
6,093,883 A 7/2000 Sanghvi et al.
6,113,558 A 9/2000 Rosenchein et al.
6,113,559 A 9/2000 Klopotek
6,120,452 A * 9/2000 Barthe et al. 600/459
6,135,971 A 10/2000 Hutchinson et al.
6,139,499 A 10/2000 Wilk
6,159,150 A 12/2000 Yale et al.
6,171,244 B1 1/2001 Finger et al.
6,176,840 B1 1/2001 Nishimura et al.
6,183,426 B1 2/2001 Akisada et al.
6,183,502 B1 2/2001 Takeuchi
6,183,773 B1 2/2001 Anderson
6,190,323 B1 2/2001 Digs
6,190,336 B1 2/2001 Duarte
6,193,658 B1 2/2001 Wendelken et al.
6,210,327 B1 4/2001 Brackett et al.
6,213,948 B1 4/2001 Barthe et al.
6,216,029 B1 4/2001 Paltieli
6,233,476 B1 * 5/2001 Strommer et al. 600/424
6,234,990 B1 5/2001 Rowe et al.
6,241,753 B1 6/2001 Knowlton
6,246,898 B1 * 6/2001 Vesely et al. 600/424
6,273,864 B1 8/2001 Duarte
6,287,257 B1 9/2001 Matichuk
6,296,619 B1 10/2001 Brisken
6,301,989 B1 * 10/2001 Brown et al. 74/490.08
6,311,090 B1 10/2001 Knowlton
6,315,741 B1 11/2001 Martin
6,322,509 B1 11/2001 Pan et al.
6,322,532 B1 11/2001 D'Sa
6,325,540 B1 12/2001 Lounsberry et al.
6,325,769 B1 12/2001 Klopotek
6,325,798 B1 12/2001 Edwards et al.
6,350,276 B1 2/2002 Knowlton
6,356,780 B1 3/2002 Licato et al.
6,361,531 B1 3/2002 Hissong
6,375,672 B1 4/2002 Aksan
6,377,855 B1 4/2002 Knowlton
6,381,497 B1 4/2002 Knowlton
6,381,498 B1 4/2002 Knowlton
6,390,982 B1 5/2002 Bova et al.
6,405,090 B1 6/2002 Knowlton
6,409,720 B1 6/2002 Hissong
6,413,253 B1 7/2002 Koop et al.
6,413,254 B1 7/2002 Hissong et al.
6,419,648 B1 7/2002 Vitek et al.
6,425,865 B1 * 7/2002 Salcudean et al. 600/437
6,425,867 B1 7/2002 Veazy
6,425,912 B1 7/2002 Knowlton
6,428,477 B1 8/2002 Mason
6,428,532 B1 8/2002 Doukas et al.
6,430,446 B1 8/2002 Knowlton
6,432,067 B1 8/2002 Martin
6,432,101 B1 8/2002 Weber
6,436,061 B1 8/2002 Costantino
6,438,424 B1 8/2002 Knowlton
6,440,071 B1 8/2002 Slayton et al.
6,440,121 B1 8/2002 Weber
6,443,914 B1 9/2002 Constantino et al.
6,453,202 B1 9/2002 Knowlton
6,461,378 B1 10/2002 Knowlton
6,470,216 B1 10/2002 Knowlton
6,491,657 B2 12/2002 Rowe
6,500,121 B1 12/2002 Slayton et al.
6,500,141 B1 12/2002 Irion et al.
6,508,774 B1 1/2003 Acker
6,511,428 B1 1/2003 Azuma
6,514,244 B2 2/2003 Pope
6,524,250 B1 2/2003 Weber
6,540,679 B2 4/2003 Slayton et al.
6,554,771 B1 * 4/2003 Buil et al. 600/459
6,569,099 B1 5/2003 Babaev
6,595,934 B1 7/2003 Hissong et al.
6,599,256 B1 7/2003 Acker
6,607,498 B2 8/2003 Eshel
6,623,430 B1 9/2003 Slayton et al.
6,626,854 B2 9/2003 Friedman et al.
6,626,855 B1 9/2003 Weng et al.
6,645,162 B2 11/2003 Friedman
6,662,054 B2 12/2003 Kreindel
6,663,627 B2 12/2003 Francischelli
6,665,806 B1 12/2003 Shimizu
6,666,835 B2 12/2003 Martin et al.
6,685,640 B1 2/2004 Fry et al.
6,692,450 B1 2/2004 Coleman et al.
6,699,237 B2 3/2004 Weber
6,719,449 B1 4/2004 Laughlin
6,719,694 B2 4/2004 Weng et al.
6,749,624 B2 6/2004 Knowlton
6,775,404 B1 * 8/2004 Pagoulatos et al. 382/154
6,824,516 B2 * 11/2004 Batten et al. 600/439
6,835,940 B2 12/2004 Morikawa et al.
6,875,176 B2 4/2005 Mourad et al.
6,887,239 B2 5/2005 Elstrom
6,905,466 B2 6/2005 Salgo et al.
6,920,883 B2 7/2005 Bessette
6,921,371 B2 7/2005 Wilson
6,932,771 B2 8/2005 Whitmore
6,936,044 B2 8/2005 McDaniel
6,936,046 B2 8/2005 Hissong
6,948,843 B2 9/2005 Laugharn et al.
6,953,941 B2 10/2005 Nakano et al.
6,958,043 B2 10/2005 Hissong
6,974,417 B2 12/2005 Lockwood
6,976,492 B2 12/2005 Ingle
6,992,305 B2 1/2006 Maezawa et al.
6,997,923 B2 2/2006 Anderson
7,006,874 B2 2/2006 Knowlton
7,020,528 B2 3/2006 Neev
7,022,089 B2 4/2006 Ooba et al.
7,058,440 B2 6/2006 Heuscher et al.
7,063,666 B2 6/2006 Weng et al.
7,070,565 B2 7/2006 Vaezy et al.
7,094,252 B2 8/2006 Koop
7,115,123 B2 10/2006 Knowlton et al.
7,142,905 B2 11/2006 Slayton et al.
7,179,238 B2 2/2007 Hissong
7,189,230 B2 3/2007 Knowlton
7,229,411 B2 6/2007 Slayton et al.
7,235,592 B2 6/2007 Muratoglu
7,258,674 B2 8/2007 Cribbs et al.
7,273,459 B2 9/2007 Desilets
7,297,117 B2 11/2007 Trucco et al.
7,347,855 B2 3/2008 Eshel
RE40,403 E 6/2008 Cho et al.
7,393,325 B2 7/2008 Barthe et al.
7,398,116 B2 * 7/2008 Edwards 600/424
7,491,171 B2 2/2009 Barthe et al.
7,615,015 B2 11/2009 Coleman
7,824,348 B2 11/2010 Barthe et al.
8,057,389 B2 11/2011 Barthe et al.
2001/0009997 A1 7/2001 Pope
2001/0014780 A1 8/2001 Martin et al.
2001/0039380 A1 11/2001 Larson et al.
2001/0041880 A1 11/2001 Brisken
2002/0000763 A1 1/2002 Jones
2002/0040199 A1 4/2002 Klopotek
2002/0040442 A1 4/2002 Ishidera
2002/0055702 A1 5/2002 Atala
2002/0062077 A1 5/2002 Emmenegger et al.
2002/0062142 A1 5/2002 Knowlton
2002/0082528 A1 6/2002 Friedman et al.

2002/0082589 A1 6/2002 Friedman et al.
2002/0095143 A1 7/2002 Key
2002/0128648 A1 9/2002 Weber
2002/0156400 A1 10/2002 Babaev
2002/0161357 A1 10/2002 Anderson et al.
2002/0165529 A1 11/2002 Danek
2002/0168049 A1 11/2002 Schriever
2002/0169394 A1 11/2002 Eppstein et al.
2002/0169442 A1 11/2002 Neev
2002/0173721 A1 11/2002 Grunwald et al.
2002/0193831 A1 12/2002 Smith
2003/0014039 A1* 1/2003 Barzell et al. 606/1
2003/0018255 A1 1/2003 Martin
2003/0028113 A1 2/2003 Gilbert et al.
2003/0032900 A1 2/2003 Ella
2003/0036706 A1 2/2003 Slayton et al.
2003/0040739 A1 2/2003 Koop
2003/0050678 A1 3/2003 Sierra
2003/0060736 A1 3/2003 Martin et al.
2003/0065313 A1 4/2003 Koop et al.
2003/0074023 A1 4/2003 Kaplan
2003/0083536 A1 5/2003 Eshel et al.
2003/0097071 A1 5/2003 Halmann et al.
2003/0125629 A1 7/2003 Ustuner
2003/0171678 A1* 9/2003 Batten et al. 600/443
2003/0176790 A1 9/2003 Slayton
2003/0191396 A1 10/2003 Sanghvi et al.
2003/0200481 A1 10/2003 Stanley
2003/0212129 A1 11/2003 Liu et al.
2003/0212351 A1 11/2003 Hissong et al.
2003/0212393 A1 11/2003 Knowlton
2003/0216795 A1 11/2003 Harth
2003/0220536 A1 11/2003 Hissong
2003/0220585 A1 11/2003 Hissong
2003/0236487 A1 12/2003 Knowlton
2004/0000316 A1 1/2004 Knowlton
2004/0001809 A1 1/2004 Brisken
2004/0002705 A1 1/2004 Knowlton et al.
2004/0015106 A1 1/2004 Coleman
2004/0030227 A1 2/2004 Littrup
2004/0039312 A1 2/2004 Hillstead et al.
2004/0039418 A1 2/2004 Elstrom et al.
2004/0059266 A1 3/2004 Fry et al.
2004/0073079 A1 4/2004 Altshuler et al.
2004/0073113 A1 4/2004 Salgo
2004/0073116 A1 4/2004 Smith
2004/0102697 A1 5/2004 Evron
2004/0143297 A1 7/2004 Ramsey
2004/0152982 A1 8/2004 Hwang et al.
2004/0186535 A1 9/2004 Knowlton et al.
2004/0206365 A1 10/2004 Knowlton
2004/0210214 A1 10/2004 Knowlton
2004/0217675 A1 11/2004 Desilets et al.
2004/0249318 A1 12/2004 Tanaka et al.
2004/0267252 A1 12/2004 Washington
2005/0033201 A1 2/2005 Takahashi et al.
2005/0055073 A1 3/2005 Weber
2005/0070961 A1 3/2005 Maki et al.
2005/0074407 A1 4/2005 Smith
2005/0080469 A1 4/2005 Larson
2005/0113689 A1 5/2005 Gritzky
2005/0137656 A1 6/2005 Malak
2005/0154313 A1 7/2005 Desilets et al.
2005/0154314 A1 7/2005 Quistgaard
2005/0154332 A1 7/2005 Zanelli
2005/0187495 A1 8/2005 Quistgaard et al.
2005/0228281 A1 10/2005 Nefos
2005/0256406 A1 11/2005 Barthe et al.
2005/0261584 A1 11/2005 Eshel
2005/0267454 A1 12/2005 Hissong et al.
2006/0004306 A1 1/2006 Altshuler
2006/0020260 A1 1/2006 Dover et al.
2006/0025756 A1 2/2006 Francischelli
2006/0042201 A1 3/2006 Curry
2006/0058664 A1 3/2006 Barthe
2006/0058707 A1 3/2006 Barthe et al.
2006/0058712 A1 3/2006 Altshuler et al.
2006/0074309 A1 4/2006 Bonnefous
2006/0074313 A1 4/2006 Slayton et al.
2006/0074314 A1 4/2006 Slayton et al.
2006/0074355 A1 4/2006 Slayton et al.
2006/0079816 A1 4/2006 Barthe et al.
2006/0079868 A1 4/2006 Makin et al.
2006/0084891 A1 4/2006 Barthe et al.
2006/0089632 A1 4/2006 Barthe et al.
2006/0089688 A1 4/2006 Panescu
2006/0111744 A1 5/2006 Makin et al.
2006/0116671 A1 6/2006 Slayton et al.
2006/0122508 A1 6/2006 Slayton et al.
2006/0122509 A1 6/2006 Desilets
2006/0161062 A1 7/2006 Arditi et al.
2006/0184069 A1 8/2006 Vaitekunas
2006/0184071 A1 8/2006 Klopotek
2006/0206105 A1 9/2006 Chopra
2006/0241440 A1 10/2006 Eshel et al.
2006/0241442 A1 10/2006 Barthe et al.
2006/0282691 A1 12/2006 Barthe et al.
2006/0291710 A1 12/2006 Wang et al.
2007/0032784 A1 2/2007 Gliklich et al.
2007/0035201 A1 2/2007 Desilets et al.
2007/0055154 A1 3/2007 Torbati
2007/0055156 A1 3/2007 Desilets et al.
2007/0087060 A1 4/2007 Dietrich
2007/0088346 A1 4/2007 Mirizzi et al.
2007/0167709 A1 7/2007 Slayton et al.
2007/0208253 A1 9/2007 Slayton et al.
2008/0071255 A1 3/2008 Barthe et al.
2008/0086054 A1 4/2008 Slayton et al.
2008/0214966 A1 9/2008 Slayton et al.
2008/0221491 A1 9/2008 Slayton et al.
2008/0275342 A1 11/2008 Barthe et al.
2008/0281237 A1 11/2008 Slayton et al.
2008/0281255 A1 11/2008 Slayton et al.
2008/0294073 A1 11/2008 Barthe et al.

FOREIGN PATENT DOCUMENTS

DE	10140064	3/2003
DE	10219217	11/2003
DE	20314479	3/2004
EP	0344773	12/1989
EP	1479412	11/1991
EP	0473553	4/1992
EP	0661029	7/1995
EP	1234566	8/2002
EP	1262160	12/2002
GB	2113099	8/1983
JP	3123559	5/1991
JP	03136642	6/1991
JP	4089058	3/1992
JP	7080087	3/1995
JP	7222782	8/1995
JP	2002078764	3/2002
JP	2003050298	2/2003
JP	2003204982	7/2003
JP	2005323213	11/2005
KR	1020010024871	3/2001
KR	1020060113930	11/2006
KR	1020070065332	6/2007
KR	1020070070161	7/2007
KR	1020070098856	10/2007
KR	1020070104878	10/2007
KR	1020070114105	11/2007
WO	WO9735518	10/1997
WO	WO9832379	7/1998
WO	WO9933520	7/1999
WO	WO9949788	10/1999
WO	0015300	3/2000
WO	WO0015300	3/2000
WO	WO0021612	4/2000
WO	WO0128623	4/2001
WO	WO0182777	11/2001
WO	WO0182778	11/2001
WO	WO0187161	11/2001
WO	0209813	2/2002
WO	WO0209813	2/2002
WO	WO0224050	3/2002
WO	WO02092168	11/2002
WO	03065347	8/2003

WO	WO03070105	8/2003
WO	WO03077833	9/2003
WO	03086215	10/2003
WO	03101530	12/2003
WO	WO03099177	12/2003
WO	2005090978	9/2005
WO	2006036870	4/2006
WO	WO2006042168	4/2006
WO	WO2006042201	4/2006

OTHER PUBLICATIONS

Alster, Tinas S., Tanzi, Elizabeth L., "Cellulite Treatment using a Novel Combination Radiofrequency, Infrared Light, and Mechanical Tissue Manipulation Device," Journal of Cosmetic & Laser Therapy, Jun. 2005, vol. 7, Issue 2, pp. 81-85.
Barthe et al., "Ultrasound therapy system and abiation results utilizing miniature imaging/therapy arrays," Ultrasonics Symposium, 2004 IEEE, Aug. 23, 2004, pp. 1792-1795, vol. 3.
Coon, Joshua et al., "Protein identification using sequential ion/ion reactions and tandem mass spectometry" Proceedings of the National Academy of Sciences of the USA, vol. 102, No. 27, Jul. 5, 2005, pp. 9463-9468.
Corry, Peter M., et al., "Human Cancer Treatment with Ultrasound", IEEE Transactions on Sonics and Ultrasonics, vol. SU-31, No. 5, Sep. 1984, pp. 444,456.
Daum et al., "Design and Evaluation of a Feedback Based Phased Array System for Ultrasound Surgery," IEEE Transactions on Ultrasonics, Feroelectronics, and Frequency Control, vol. 45, No. 2, Mar. 1998, pp. 431-438.
Davis, Brian J., et al., "An Acoustic Phase Shift Technique for the Non-Invasive Measurement of Temperature Changes in Tissues", 1985 Ultrasonics Symposium, pp. 921-924.
Gliklich et al., Clinical Pilot Study of Intense Ultrasound therapy to Deep Dermal Facial Skin and Subcutaneous Tissues, Arch Facial Plastic Surgery, Mar. 1, 2007, vol. 9.
Hassan et al., "Structure and Applications of Poly(vinyl alcohol) Hydrogels Produced by Conventional Crosslinking or by Freezing/ Thawing Methods," advanced in Polymer Science, 2000, pp. 37-65, vol. 153.
Hassan et al., "Structure and Morphology of Freeze/Thawed PVA Hydrogels," Macromolecules, Mar. 11, 2000, pp. 2472-2479, vol. 33, No. 7.
Husseini et al, "The Role of Cavitation in Acoustically Activated Drug Delivery," J. Control Release, Oct. 3, 2005, pp. 253-261, vol. 107(2).
Husseini et al. "Investigating the mechanism of accoustically activated uptake of drugs from Pluronic micelles," BMD Cancer 2002, 2:20k, Aug. 30, 2002, pp. 1-6.
Jenne, J., et al., "Temperature Mapping for High Energy US-Therapy", 1994 Ultrasonics Symposium, pp. 1879-1882.
Johnson, S.A., et al., "Non-Intrusive Measurement of Microwave and Ultrasound-Induced Hyperthermia by Acoustic temperature Tomography", Ultrasonics Symposium Proceedings, pp. 977-982.
Makin et al, "B-Scan Imaging and Thermal Lesion Monitoring Using Miniaturized Dual-Functionality Ultrasound Arrays," Ultrasonics Symposium, 2004 IEEE, Aug. 23, 2004, pp. 1788-1791, vol. 3.
Makin et al, "Miniaturized Ultrasound Arrays for Interstitial Ablation and Imaging," UltraSound Med. Biol. 2005, Nov. 1, 2005, pp. 1539-1550, vol. 31(11).
Makin et al., "Confirmal Bulk Ablation and Therapy Monitoring Using Intracorporeal Image-Treat Ultrasound Arrays", 4th International Symposium on Therapeutic Ultrasound, Sep. 19, 2004.
Manohar et al, "Photoaccoustic mammography laboratory prototype: imaging of breast tissue phantoms," Journal of Biomedical Optics, Nov./Dec. 2004, pp. 1172-1181, vol. 9, No. 6.
Mast et al, "Bulk Ablation of Soft Tissue with Intense Ultrasound; Modeling nad Experiments," J. Acoust. Soc. Am., Oct. 1, 2005, pp. 2715-2724, vol. 118(4).
Paradossi et al., "Poly(vinyl alcohol) as versatile biomaterial for potential biomedical applications," Journal of Materials Science: Materials in Medicine, 2003, pp. 687-691, vol. 14.
Reid, Gavin, et al., "Tandem Mass spectrometry of ribonuclease A and B: N-linked glycosylation site analysis of whole protein ions," Analytical Chemistry. Feb. 1, 2002, vol. 74, No. 3, pp. 577-583.
Righetti et al, "Elastographic Characterization of HIFU-Induced Lesions in Canine Livers," 1999, Ultrasound in Med & Bio, vol. 25, No. 7, pp. 1099-1113.
Mitragotri, Samir; "Healing sound: the use of ultrasound in drug delivery and other therapeutic applications," Nature Reviews; Drug Delivery, pp. 255-260, vol. 4.
Sanghvi, N.T., et al., "Transrectal Ablation of Prostrate Tissue Using Focused Ultrasound," 1993 Ultrasonics Symposium, IEEE, pp. 1207-1210.
Seip, Ralf, et al., "Noninvasive Detection of Thermal Effects Due to Highly Focused Ultrasonic Fiels," IEEE Symposium, pp. 1229-1232, vol. 2, Oct. 3-Nov. 1993.
Seip, Ralf, et al., "Noninvasive Estimation of Tissue Temperature Response to Heating Fields Using Diagnostic Ultrasound," IEEE Transactions on Biomedical Engineering, vol. 42, No. 8, Aug. 1995, pp. 828-839.
Smith, Nadine Barrie, et al., "Non-Invasive In Vivo Temperature Mapping of Ultrasound Heating Using Magnetic Resonance Techniques", 1994 Ultrasonics Symposium, pp. 1829-1832, vol. 3.
Surry et al., "Poly(vinyl alcohol) cryogel phantoms for use in ultrasound and MR imaging," Phys. Med. Biol., Dec. 6, 2004, pp. 5529-5546, vol. 49.
Syka J. E. P. et al., "Peptide and Protein Sequence Analysis by Electron Transfer Dissociation Mass Spectometry," Proceedings of the National Academy of Sciences of USA, National Academy of Aceince, Washington, DC, vol. 101, No. 26, Jun. 29, 2004, pp. 9528-9533.
Ueno, S., et al., "Ultrasound Thermometry in Hyperthermia", 1990 Ultrasonic Symposium, pp. 1645-1652.
Wang, H., et al., "Limits on Focused Ultrasound for Deep Hyperthermia", 1994 Ultrasonic Symposium, Nov. 1-4, 1994, pp. 1869-1872, vol. 3.
White et al "Selective Creation of Thermal Injury Zones in the Superficial Musculoaponeurotic System Using Intense Ultrasound Therapy," Arch Facial Plastic Surgery, Jan./Feb. 2007, vol. 9, No. 1.
Sassen, Sander, "ATI's R520 architecture, the new king of the hill?" http://www.hardwareanalysis.com/content/article/1813, Sep. 16, 2005, 2 pages.
Wasson, Scott, "NVIDIA's GeFroce 7800 GTX graphics processor Power MADD," http://techreport.com/reviews/2005q2/geforce-7800gtx/index.x?pg=1, Jun. 22, 2005, 4 pages.
Chen, L. et al., ""Effect of Blood Perfusion on the ablation of liver perenchyma with high intensity focused ultrasound,"" Phys. Med. Biol; 38:1661-1673; 1993b.
Damianou et al., Application of the Thermal Dose Concept for Predicting the Necrosed Tissue Volume During Ultrasound Surgery, 1993 IEEE Ultrasound Symposium, pp. 1199-1202.
Fry, W.J. et al., "Production of Focal Destructive Lesions in the Central Nervous System with Ultrasound," J. Neurosurg., 11:471-478; 1954.
Harr, G.R. et al., "Tissue Destruction with Focused Ultrasound in Vivo," Eur. Urol. 23 (suppl. 1):8-11; 1993.
Jeffers et al., "Evaluation of the Effect of Cavitation Activity on Drug-Ultrasound Synergisms," 1993 IEEE Ultrasonics Symposium, pp. 925-928.
Madersbacher, S. et al., "Tissue Ablation in Bening Prostatic Hyperplasia with High Intensity Focused Ultrasound," Dur. Urol., 23 (suppl. 1):39-43; 1993.
Saad et al., "Ultrasound-Enhanced Effects of Adriamycin Against Murine Tumors," Ultrasound in Med. & Biol. vol. 18, No. 8, pp. 715-723 (1992).
Simon et al., "Applications of Lipid-Coated Microbubble Ultrasonic Contrast to Tumor Therapy," Ultrasound in Med. & Biol. vol. 19, No. 2, pp. 123-125 (1993).
Talbert, D. G., "An Add-On Modification for Linear Array Real-Time Ultrasound Scanners to Produce 3D Displays," UTS Int'l 1977 Brighton, England (Jun. 28-30, 1977) pp. 57-67.
Tata et al., "Interaction of Ultrasound and Model Membrane Systems: Analyses and Predictions," American Chemical Society, Phys. Chem. 1992, 96, pp. 3548-3555.

* cited by examiner

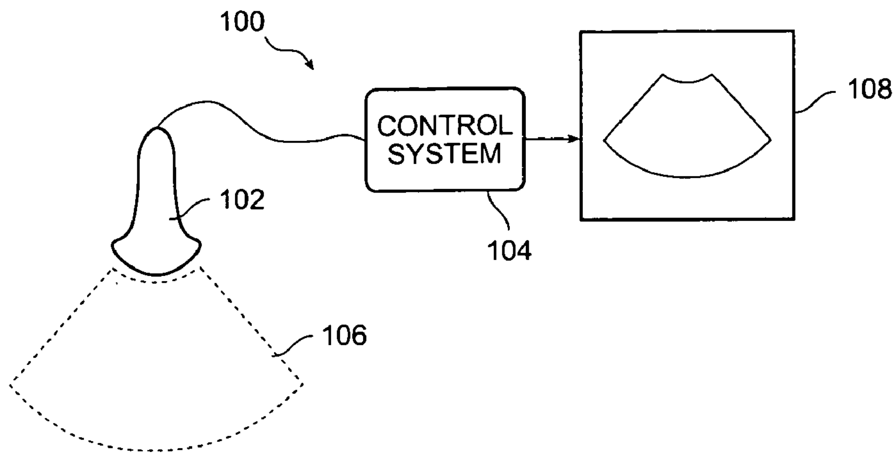


FIG. 1A

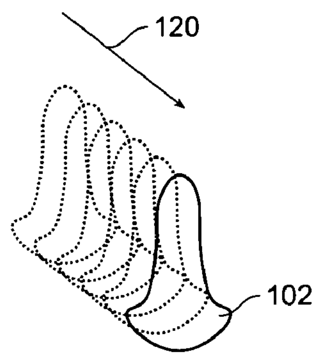


FIG. 1B

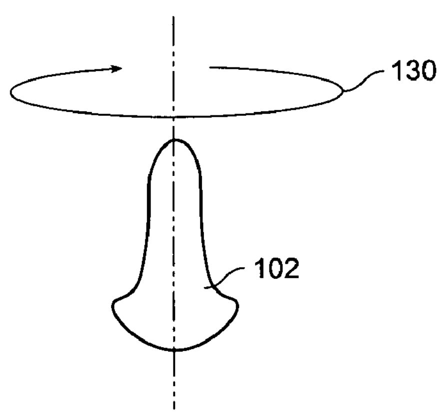


FIG. 1C

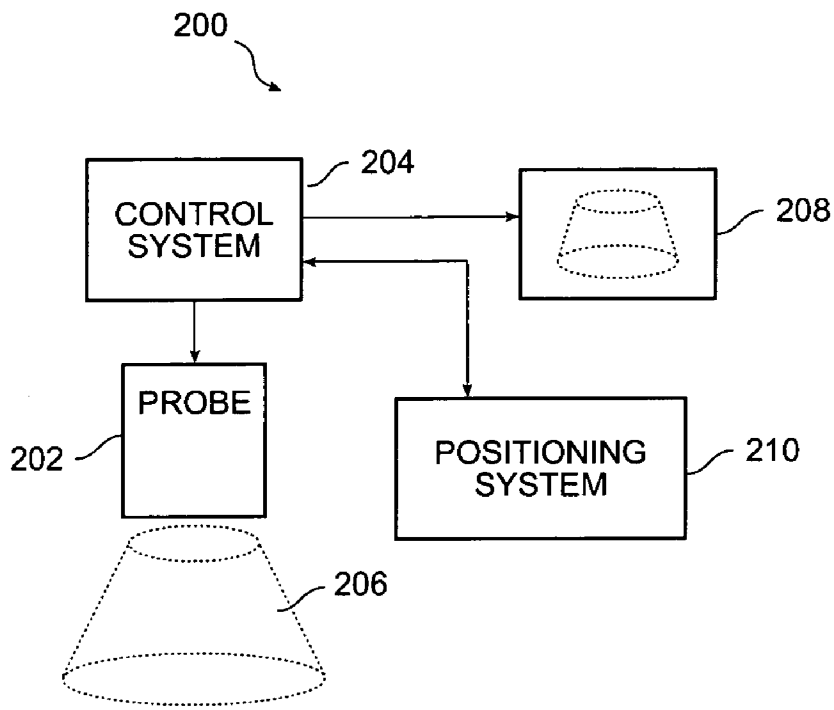

200
204
CONTROL SYSTEM
208
PROBE
202
POSITIONING SYSTEM
210
206

FIG. 2A

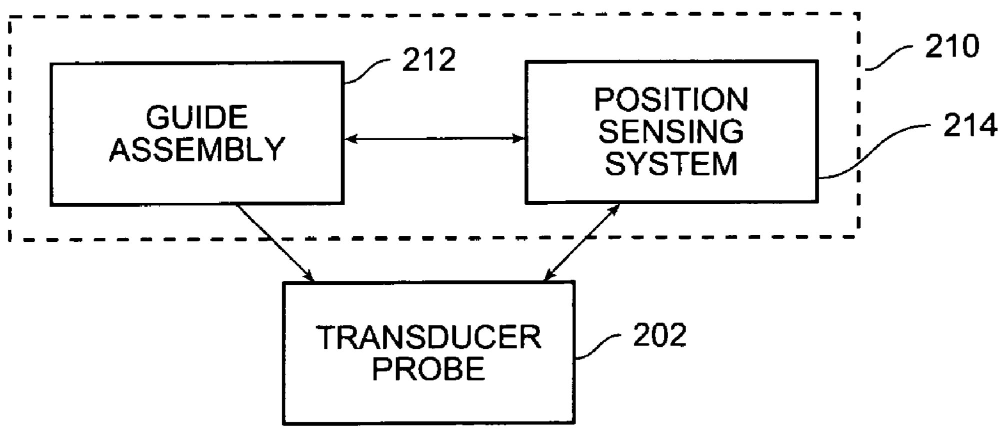

GUIDE ASSEMBLY
212
POSITION SENSING SYSTEM
210
214
TRANSDUCER PROBE
202

FIG. 2B

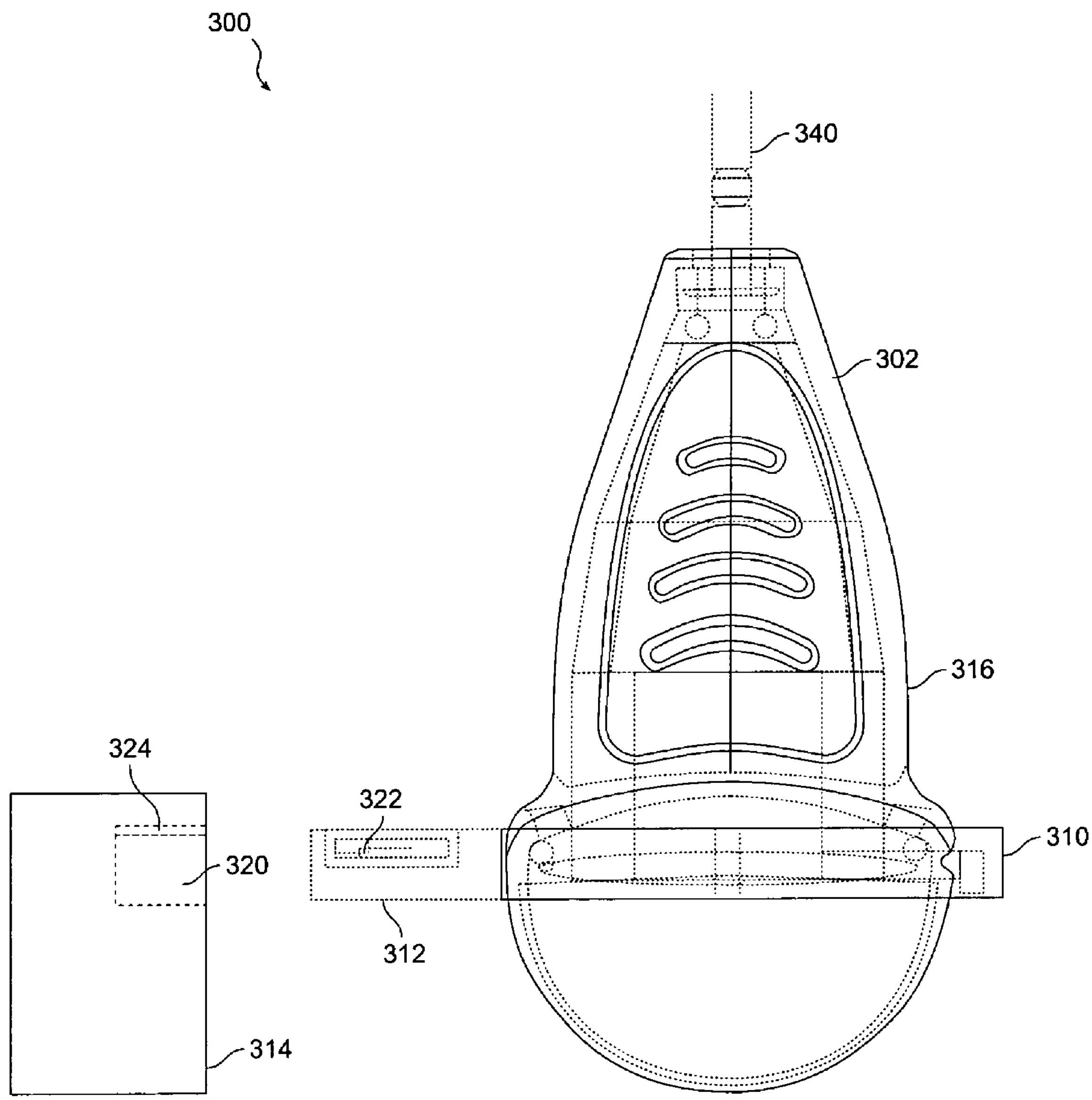


FIG. 3

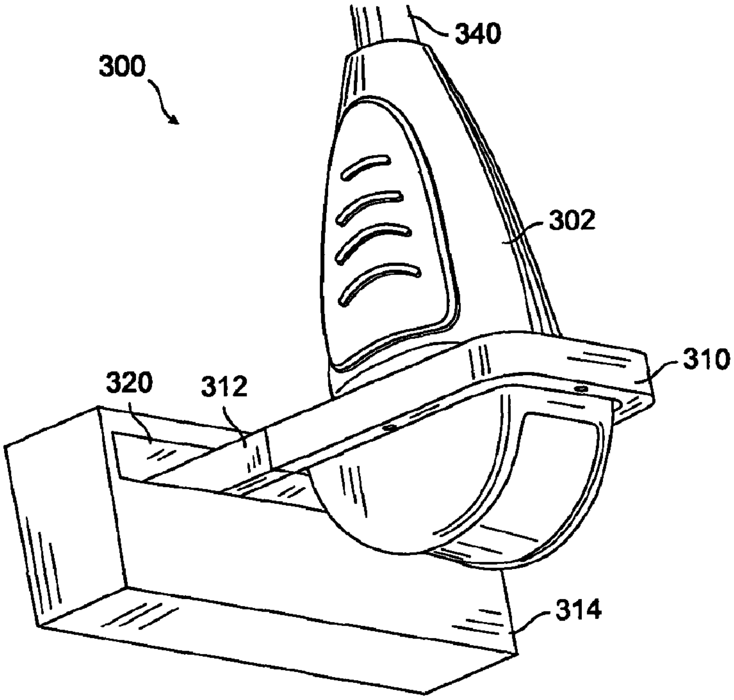


FIG. 4

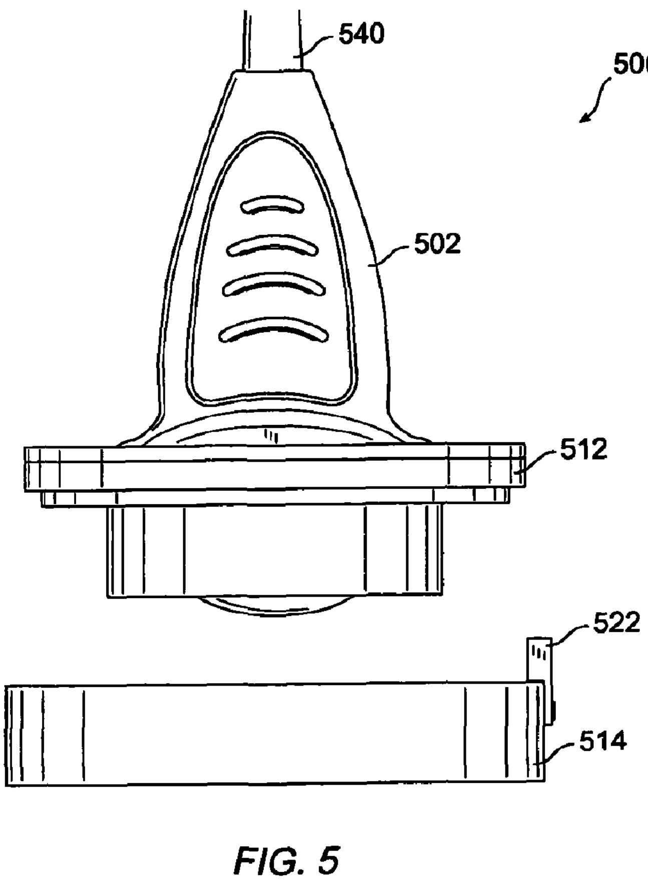


FIG. 5

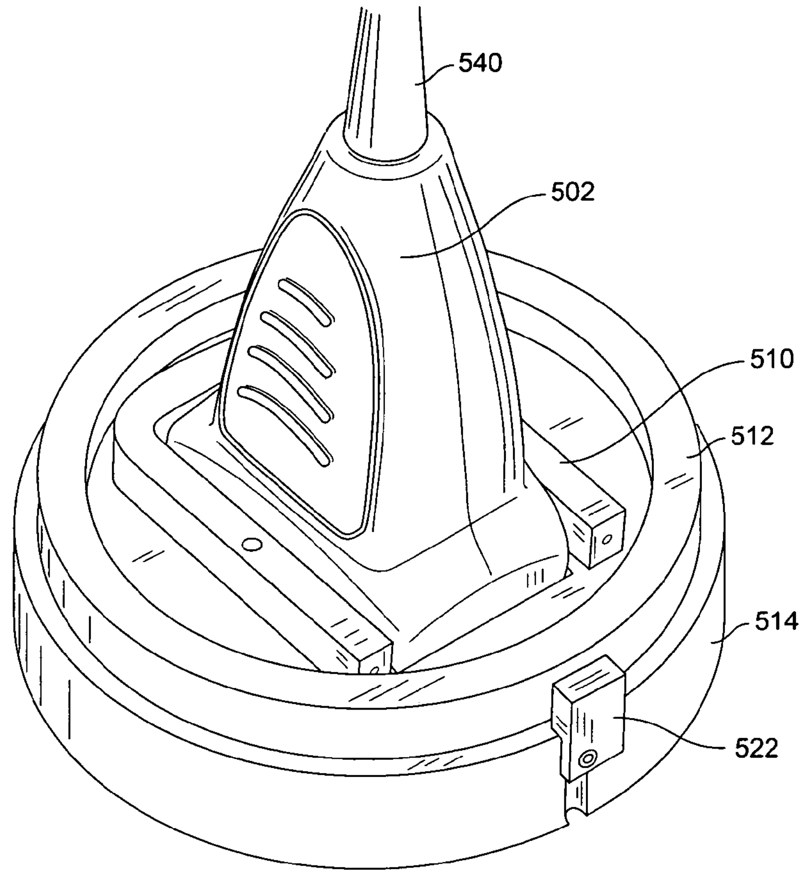


FIG. 6

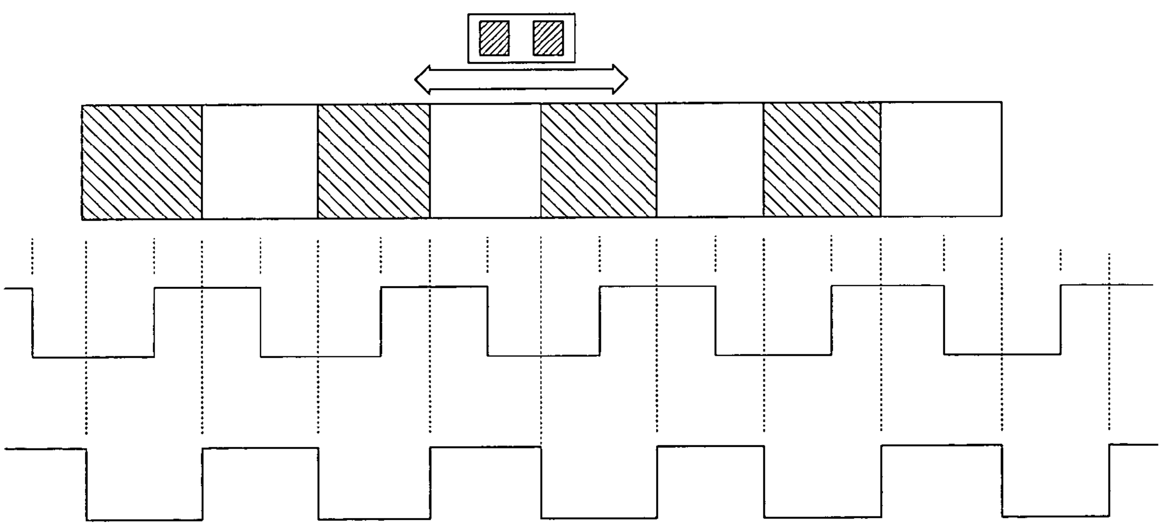


FIG. 7

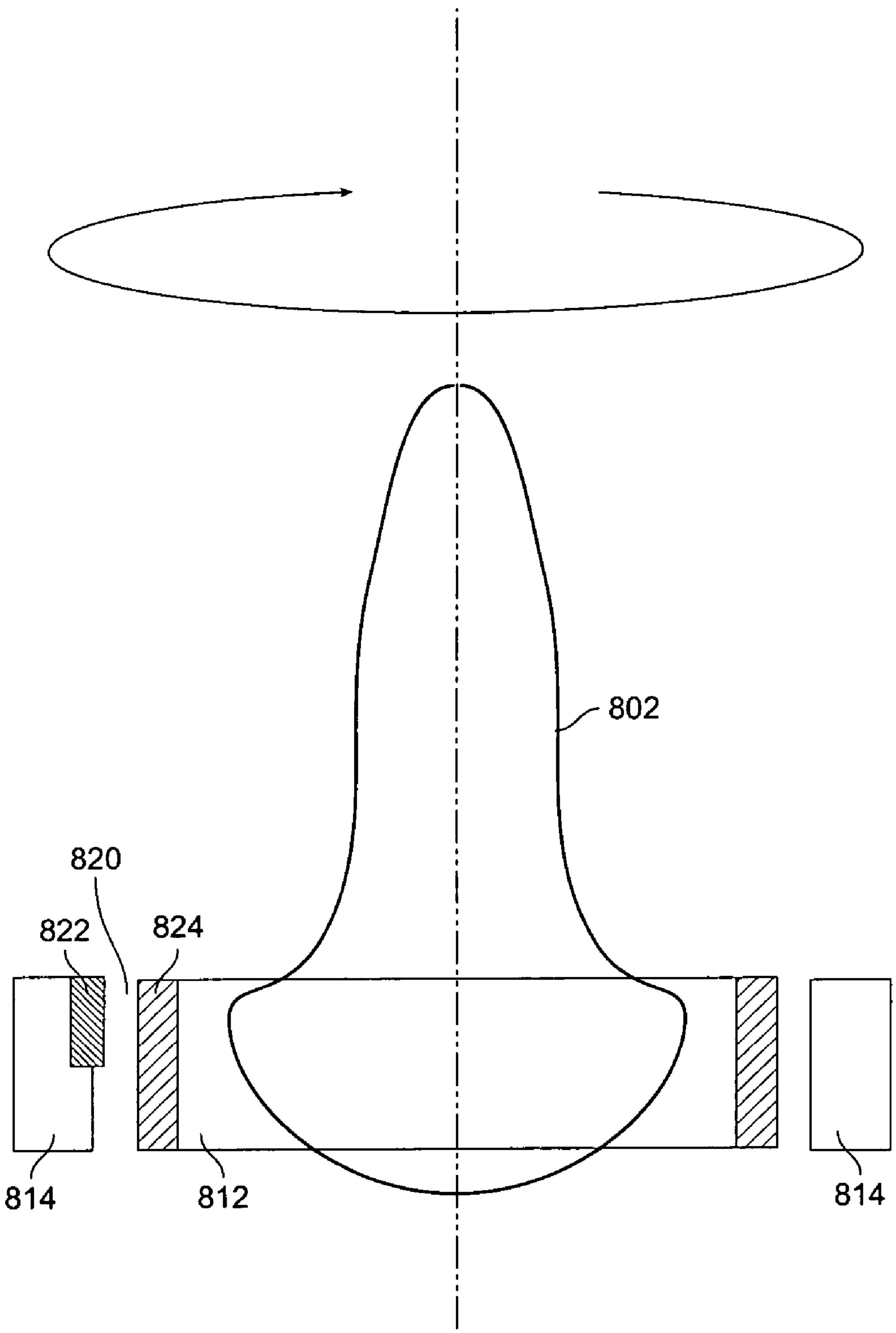


FIG. 8

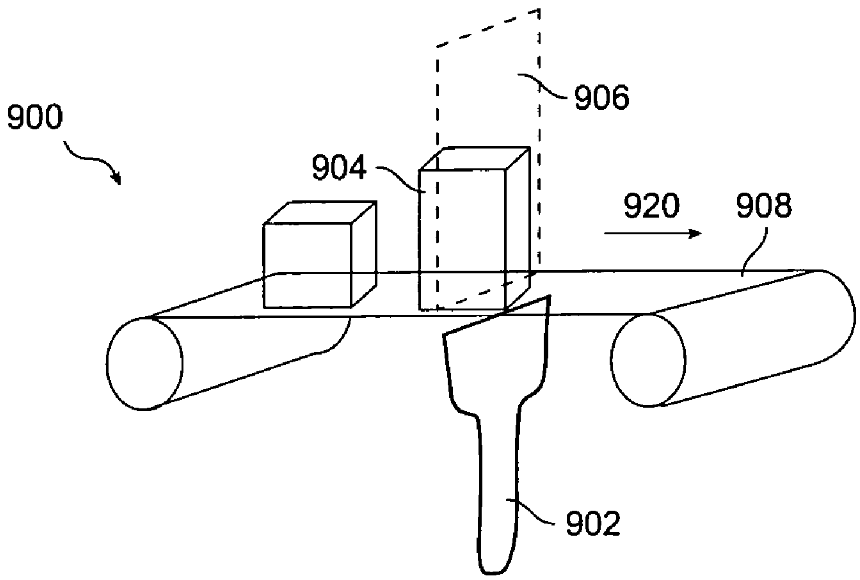


FIG. 9A

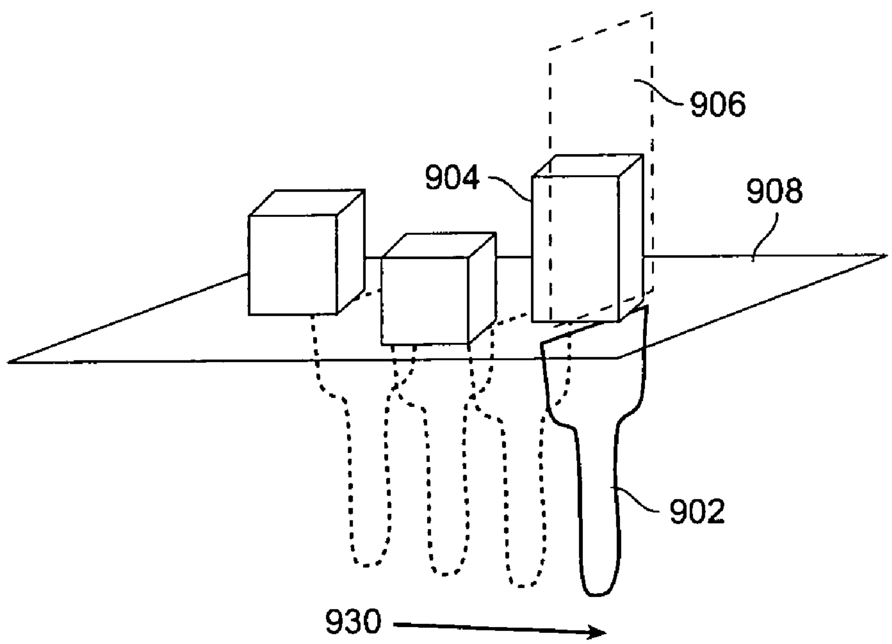


FIG. 9B

METHOD AND SYSTEM FOR CONTROLLED SCANNING, IMAGING AND/OR THERAPY

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claim priority from U.S. Provisional Application No. 60/570,145, entitled "Method and System for Three-Dimensional Scanning and Imaging" and filed May 12, 2004.

FIELD OF INVENTION

The present invention relates to imaging and treatment systems, and in particular to a method and system for controlled scanning, imaging and/or therapy.

BACKGROUND OF THE INVENTION

Ultrasound images are typically generated and displayed as two-dimensional (2-D) image slices. For example, with reference to FIG. **1**A, a conventional ultrasound imaging system **100** comprising a transducer **102** and a control system **104** are configured to obtain two-dimensional imaging information **106** and display two-dimensional imaging slices **108**. However, it is often desirable to acquire a whole volume of data in the form of multiple image planes and render it in a three-dimensional (3-D) format, such as for viewing a fetus. Acquiring multiple image slices can be performed by moving the imaging probe in a manner to produce volumetric information. The quality of the computer-rendered 3-D image (the output) is closely related to spatial sampling of the volume-of-interest (the input data). Specifically, for ease and accuracy of the 3-D reconstruction, it would be desirable for the input image planes to be configured a minimum distance apart to avoid spatial aliasing, as well as in a defined attitude and position to avoid gross spatial distortions in rendering based on assumptions about the probe's motion. Unfortunately, prior art methodologies cannot provide such features.

For example, one shortcoming of so-called "free-hand" 3-D scanning is the lack of precision and repeatability in which the 3-D volume is interrogated due to spatially and temporally imprecise angular and linear displacements. As a result a number of pitfalls exist. As a first example, if sensors record the attitude and position of the probe, it is still possible to over- and/or under-sample the volume-of-interest. Second, even if the volume is adequately sampled, the random nature of the input data orientation requires excessive mathematical interpolations to compute a 3-D image in a uniform output grid. Third, if no sensors are used image frame correlation methods cannot accurately ascertain the relative orientation of image planes. Finally, even if six-degree-of-freedom sensors are utilized, such sensors are expensive and have limited range. In fact, what is desirable is motion having a single degree-of-freedom.

Some methodologies have used mechanical fixtures with water baths (for acoustic coupling) as well as motorized assemblies to move an imaging probe in one dimension. However, such mechanisms can be extremely cumbersome and unwieldy for human scanning and may pose safety hazards if designed improperly.

SUMMARY OF THE INVENTION

A method and system for controlled scanning, imaging and/or therapy are provided. In accordance with one aspect, an exemplary method and system are configured to suitably control an imaging probe within a one-degree of freedom. With such control, an exemplary method and system can facilitate three-dimensional imaging. For example, an exemplary method and system can enable multiple two-dimensional image planes to be collected in a manner to provide an accurate and computationally efficient three-dimensional image reconstruction while providing the user with a user-friendly mechanism for acquiring three-dimensional images. In accordance with another aspect of the present invention, an exemplary method and system can allow therapeutic treatment to occur along a prescribed path or pattern. For example, treatments that would normally occur at a single point in space become a line or other guided path after scanning in the controlled pattern, while line treatments scanned along a path can suitably become a matrix of treatments.

In accordance with an exemplary embodiment, an exemplary scanning and imaging system comprises an imaging probe, a control system, a positioning system and a display system. The imaging probe can comprise various probe and/or transducer configurations. For example, the imaging probe can also be configured for a combined imaging/therapy probe, or simply replaced with a therapy probe. The control system and display system can also comprise various configurations for controlling probes and displaying images, including for example a microprocessor with 3-D reconstruction software with a plurality of input/output devices.

In accordance with an exemplary embodiment, a positioning system is configured for facilitating controlled movement of the imaging probe within one-degree of freedom. In accordance with an exemplary embodiment, the positioning system comprises a guide assembly and a position sensing system. The guide assembly is configured to provide pure rectilinear or rotational motion of the probe during scanning operation while the position sensing system is configured to detect the direction of movement and/or position of the probe during scanning.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter of the invention is particularly pointed out in the concluding portion of the specification. The invention, however, both as to organization, structure and method of operation, may best be understood by reference to the following description taken in conjunction with the accompanying drawing figures, in which like parts may be referred to by like numerals:

FIG. **1**A is a schematic diagram of a 2-D region-of-interest being scanned by a probe connected to a conventional imaging system and display unit, which renders a 2-D image;

FIG. **1**B is a schematic diagram illustrating one-degree-of-freedom rectilinear motion for a probe in accordance with an exemplary embodiment of the present invention;

FIG. **1**C is a schematic diagram representing one-degree-of-freedom rotational motion of a probe in accordance with an exemplary embodiment of the present invention;

FIG. **2**A is a block diagram of an exemplary scanning and imaging system in accordance with an exemplary embodiment of the present invention;

FIG. **2**B is a block diagram of an exemplary positioning system configured with an imaging probe in accordance with an exemplary embodiment of the present invention;

FIG. **3** is a side view of an imaging probe configured with an exemplary guide assembly and a position sensing system for rectilinear motion in accordance with an exemplary embodiment of the present invention;

FIG. **4** is an isometric view of the imaging probe configured with an exemplary guide assembly and a position sensing system for rectilinear motion in accordance with an exemplary embodiment of the present invention;

FIG. **5** is an exploded side view of an imaging probe configured with an exemplary guide assembly and a position sensing system for rotational motion in accordance with an exemplary embodiment of the present invention;

FIG. **6** is an isometric view of an imaging probe configured with an exemplary guide assembly and a position sensing system for rotational motion in accordance with an exemplary embodiment of the present invention;

FIG. **7** is a schematic diagram of an output signal for a quadrature position sensor illustrating relative displacement and direction of displacement between an encoder element and a position sensor in accordance with an exemplary embodiment of the present invention;

FIG. **8** is a cross-sectional view of a guide assembly for rotational motion in accordance with an exemplary embodiment of the present invention; and

FIG. **9** is a diagram of an exemplary scanning and/or treatment system within a continuous flow arrangement in accordance with an exemplary embodiment of the present invention.

DETAILED DESCRIPTION

The present invention may be described herein in terms of various functional components and processing steps. It should be appreciated that such components and steps may be realized by any number of hardware components configured to perform the specified functions. For example, the present invention may employ various medical treatment devices, visual imaging and display devices, input terminals and the like, which may carry out a variety of functions under the control of one or more control systems or other control devices. In addition, the present invention may be practiced in any number of medical contexts and that the exemplary embodiments relating to an imaging, therapy and/or scanning system as described herein are merely indicative of exemplary applications for the invention. For example, the principles, features and methods discussed may be applied to any medical application. Further, various aspects of the present invention may be suitably applied to other industrial, manufacturing or engineering applications, such as the inspection of materials such as steel, plastics, concrete or wood. In addition, while various components and devices may be described as coupled together, such coupling can be realized through direct connection of such components and devices, or the coupling together of such components and devices through the interconnection of one or more other components and devices.

In accordance with various aspects of the present invention, a method and system for controlled scanning, imaging and/or therapy are provided. In accordance with one aspect, an exemplary method and system are configured to suitably control an imaging probe within a one-degree of freedom. With such control, an exemplary method and system can facilitate three-dimensional imaging. For example, an exemplary method and system can enable multiple two-dimensional image planes to be collected in a manner to provide an accurate and computationally efficient three-dimensional image reconstruction while providing the user with a user-friendly mechanism for acquiring three-dimensional images.

In accordance with an exemplary embodiment, with reference to FIG. **2**, an exemplary scanning and imaging system **200** comprises an imaging probe **202**, a control system **204**, a positioning system **210** and a display system **208**.

Imaging probe **202** can comprise various probe and/or transducer configurations. For example, imaging probe **202** can comprise any ultrasound transducer element configured for facilitating imaging of a treatment region. Imaging probe **202** can also comprise any other imaging mechanism, such as lasers, or other light source devices. Imaging probe **202** is configured to obtain 2-dimensional sliced images of a treatment region **206**. In addition, imaging probe **202** can comprise other functions. For example, imaging probe **202** can also be configured as a combined imaging and/or therapy probe, a combined imaging and/or therapy and/or temperature monitoring probe, a combined therapy and other tissue parameter monitoring probe, or other combination of tissue parameter monitoring functions. Moreover, imaging probe **202** can be suitably replaced with a therapy-only probe or other single tissue parameter-type probes. Probe **202** can also include those used for applications in urology, such as for bladder volume; obstetrics, such as for fetal viewing; dermatology, such as for forming imaging scan lines and/or therapeutic lesions; and other therapy, and/or imaging/therapy probes such as multi-directional, variable depth, and/or ultra-high frequency probes, as disclosed in U.S. patent application Ser. No. 10/944,499, filed Sep. 16, 2004, in U.S. patent application Ser. No. 10/944,500, filed Sep. 16, 2004 and in U.S. Application No. 60/616,356, filed Oct. 6, 2004, hereby incorporated by reference in their entireties. Imaging, therapy, and/or imaging/therapy probes can be electronic (array-based) or mechanically scanned probes such as those with a direct-drive mechanism and/or linkage mechanism for imaging or treatment in sectors (arcs), lines, or other more complex patterns, e.g. 3-D paths within the probe housing.

Imaging probe **202** can also be configured within any housing structure or enclosure, and can be suitably connected to control system **204** in various manners. With momentary reference to an exemplary embodiment illustrated in FIG. **3**, an imaging probe **302** can comprise an imaging transducer configured within a housing **316**, with a cable **340** configured to couple to a control system.

Control system **204** and display system **208** can also comprise various configurations for controlling probes and displaying images or other information. For example, control system **204** can comprise any conventional microprocessor-based or other computational device. In accordance with an exemplary embodiment, control system **204** comprises a microprocessor with 3-D reconstruction software. Such 3-D software can be configured to interpolate, filter, and/or threshold incoming 2-D image slices, along with positional information, and correlate such information among any other image processing functions to render a 3-D image in a variety of display formats. The 3-D software and/or other resident software may also guide the user with instructions and feedback before, during, and after the 3-dimensional scanning. Control system **204** can also include a plurality of input/output devices. For example, one or more limit switches or other switches, indicators, and/or audible signaling mechanisms to detect or indicate a particular position, e.g., a home position, a user-actuated function, or serve any other function, can be provided. Control system **204** can be communicatively coupled to imaging probe **202**, positioning system **210** and display system **208** in any manner now known or hereinafter devised.

Display system **208** is configured to display any portion of the two-dimensional slices, or any other relevant information collected from imaging probe **202**, or processed by control system **204**. In accordance with an exemplary embodiment, display system **208** is configured to display 3-dimensional images provided by imaging system **200**. Display system **208** can comprise any display configuration or device for displaying images and/or information and data. Display system **208** can also be communicatively coupled to control system **204** in any manner, such as by direct cabling, wireless coupling, and/or any combination thereof or any other communication mechanisms.

Positioning system **210** is configured for facilitating controlled movement of imaging probe **202** within one-degree of freedom. For purposes of this disclosure, the term "one degree of freedom" comprises any prescribed path or guide such as a straight line, curvilinear line, piecewise linear and/or curvilinear collection of points, axis of rotation and/or combination thereof in two or three dimensions such that a known geometric travel or scan path is achieved. For example, with reference to FIG. **1**B, positioning system **210** can be configured to permit substantially rectilinear movement **120** of probe **202**, or with reference to FIG. **1**C, positioning system **210** can be configured to permit substantially rotational movement **130** of probe **202**. Positioning system **210** can also be configured for any other controlled movement within one-degree of freedom, such as, for example, translational movement of probe **202** about treatment region **206**, or any other movement comprising curvilinear, piecewise linear and/or curvilinear collection of points, variable axis of rotation and/or combination thereof in two or three dimensions. In addition, positioning system **210** can facilitate manual movement, automated movement, such as by a stepper motor or any other automated movement device, or any combination of manual and automated movement systems. Moreover, while the exemplary embodiment illustrates positioning system **210** configured for control of an imaging probe, positioning system **210** can also be configured for control of movement of a combined imaging/therapy probe, a therapy-only probe, or any other configuration of ultrasound or medical probes.

In accordance with an exemplary embodiment, with reference to FIG. **2**B, positioning system **210** comprises a displacement guide assembly **212** and a position sensing system **214**. Displacement guide assembly **212** is configured to provide controlled movement of a probe **202**, such as rectilinear, rotational, translational or other controlled motion, with automated and/or manual operation, while position sensing system **214** is configured to detect the direction and position of probe **202** during scanning operation.

In accordance with an exemplary embodiment, displacement guide assembly **212** can be configured for rectilinear movement. For example, with reference to FIGS. **3** and **4**, a guide assembly can comprise a holder device **310** and a stationary guide **314**. Holder device **310** is configured to enclose, surround or otherwise attach to probe **302** in a substantially rigid manner, and can comprise various shapes and configurations. In accordance with an exemplary embodiment, holder device **310** comprises a vane-like device that suitably encloses probe **302** on both sides as well as a backside opposite of stationary guide **314**, such as for example, a biopsy needle guide configured to geometrically align a biopsy needle; however, holder device **310** can also be configured to enclose on only the sides and/or one side of probe **302**, and can be configured in any shape or manner to facilitate a restriction or control of movement of probe **302** relative to stationary guide **314**. In addition, holder device **310** can be configured for a quick-engagement and/or attachment to imaging probe **302**, such as through a spring clamp or other like device, as well as a more fixed engagement, such as through screw, glue or other more fixed attachments.

Holder device **310** comprises a guide member **312** that can be slidably inserted into a slot **320** of stationary guide **314**. Guide member **312** and slot **320** can comprise various sizes, shapes and configurations for allowing slidable insertion to facilitate rectilinear or other like movement. For example, while guide member **312** comprises a square or rectangular configuration in accordance with exemplary embodiment illustrated in FIGS. **3** and **4**, guide member **312** can also comprise circular, octagonal, or any other configurations capable of being slidably inserted within slot **320**, i.e., guide member **312** does not need to have substantially the same geometric shape or configuration as slot **320**, but only capable of being slidably inserted. Guide member **312** can comprise a separate component suitably attached to holder **310** in any manner, or can comprise a unitary member with holder **310**, such as comprising a tip-end portion of holder **310**. Slot **320** can comprise any slot, raceway, groove or other like guiding path to facilitate and/or restrict the freedom of movement of guide member **312**, and thus holder **310** and probe **302**, within during scanning operation. The combination and/or insertion of member **312** within slot **320** preclude any angular displacement (e.g., yaw, pitch, or roll) and further allow displacement along only one axis, namely, the axis defined by slot **320**. To the extent that slot **320** provides other displacement orientations, e.g., a wave-like pattern, then guide member **312** will suitably follow such other displacement orientations during scanning.

In accordance with another exemplary embodiment, displacement guide assembly **212** can be configured for rotational movement. For example, with reference to FIGS. **5** and **6**, a guide assembly can comprise a rotary device **512** and a stationary guide **514**. Rotary device **512** is configured to enclose or surround probe **502**, such as probe **502** being configured within a vane member **510** or other holder device configuration and placed within rotary device **512**, or probe **502** being configured directly within rotary device **512** without use of vane member **510** or any other holder member. Stationary guide **514** is configured to facilitate controlled rotational movement of rotary device **512**. For example, in accordance with an exemplary embodiment, rotary device **512** can comprise essentially one-half of a rotary bearing assembly and stationary guide **514** comprising the other half of a rotary bearing. In accordance with another exemplary embodiment, rotary device **512** and stationary guide **514** can also be configured with a ball bearing arrangement by utilizing a sleeve bearing or assembly such that stationary guide **514** comprises a body of revolution, such as a cylinder, with an inner portion substantially and closely fitting around an outward surface of imaging and/or therapy probe **502**.

In accordance with an exemplary embodiment, rotary device **512** can comprise a guide member and stationary guide **514** comprises a raceway or slot component configured to engage with the guide member of rotary device **512**, such as the engagement to permit rotational movement within one-degree of freedom. For example, with momentary reference to FIG. **8**, a probe **802** can be configured within a rotary device **812** and defining a slot **820** disposed between rotary device **812** and stationary guide **814**. In other words, rotary device **512** can have an outer circumference configured slightly smaller than an inner perimeter of stationary guide **514** such as to permit rotary device **512** to reside within a tight or otherwise restricted fashion as defined by slot **820** to allow rotational movement of rotary device **812** and probe **802** in a controlled manner allowing one-degree of freedom. In accordance with another exemplary embodiment, rotary device can be configured with a guide member that protrudes outward and slidaby engages within a slot or raceway configured within stationary guide **514**, such as for example slot **320** within stationary guide **314**. Accordingly, rotary device **512** and stationary guide **514** can comprise various sizes, shapes and configurations to facilitate controlled rotational movement of probe **502** about a region of interest.

In accordance with an exemplary embodiment, stationary guide **514** allows rotation of probe **502** along the same central axis, rotating in a single plane; however, rotation can also be permitted in a manner outside the same central axis to maintain spatial control, e.g., in some translational manner. For example, probe **502** can be controllably moved in an arc, i.e. a fixed radius from the center of rotation, such that the probe **502** (or its scan plane) is oriented in a position parallel to the axis of rotation, perpendicular to the axis of rotation, or tilted in a variable orientation with respect to the axis of rotation. Such configurations can be particularly useful in the instance of three dimensional scanning of an annular region of space, while the perpendicular configuration can allow scanning of the inside of a cylinder or cylindrical section, and a tilted probe can allow scanning of a conic section.

While scanning and imaging systems **300** and **500** can be suitably configured to facilitate three-dimensional imaging, in accordance with another aspect of the present invention, an exemplary method and system can also allow therapeutic treatment to occur along a controlled, prescribed path or pattern. For example, therapeutic treatments that would normally occur at a single point in space become a line or other guided path after scanning in the controlled pattern, while line treatments scanned along a path can suitably become a matrix of treatments, while an initial matrix of treatment can become a denser matrix or pattern.

Position sensing system **214** is configured to determine position and/or direction during the controlled rectilinear, rotational and/or translational or other controlled movement. Position sensing system **214** can also provide feedback over time that can also be used to control therapy or imaging functions, such as, for example, the spatial and/or temporal placement of therapeutic lesions, or any other like therapeutic treatment.

For example, in accordance with an exemplary embodiment, with reference again to FIGS. **3** and **4**, a position sensing system can comprise a position sensor **322** and an encoder element **324**, with position sensor **322** configured within or otherwise coupled to holder device **310**, e.g., attached to guide member **312**, and configured to interact with encoder element **324** within stationary guide **314** to provide position feedback to a control system during rectilinear movement. In accordance with another exemplary embodiment, position sensor **322** can be integrated inside imaging probe **302** and interfaced to a control system **204**. In such a case, encoder element **324** can be placed on stationary guide **314** such that it can be detected by position sensor **322**. In accordance with other exemplary embodiments, position sensor **322** can be attached to or configured within stationary guide **314** and encoder element **324** can be attached to or configured within guide member **312**, holder device **310** and/or probe **302**.

Position sensor **322** and encoder element **324** can comprise various types of components and configurations. For example, position sensor **322** can comprise a quadrature Hall effect type sensor and encoder element **324** can comprise a multipole flexible magnetic strip, or position sensor **322** can comprise an optical quadrature sensor and encoder strip **324** comprise an alternately optically reflecting and absorbing (opaque) strips configuration. With momentary reference to FIG. **7**, a schematic diagram of an output signal for a quadrature position sensor is provided, such as position sensor **322**, that outputs quadrature square wave signals that describe the relative displacement and direction of displacement between encoder strip **324** and position sensor **322**. Position sensor and encoder can also comprise analog/digital magnetic field sensing integrated circuit(s) and magnetic field producing device(s), such as one or more permanent magnets, whereby rotary, 1-D, 2-D, or 3-D positioning information is derived by measuring magnetic field gradients and field strengths at more than one location on the sensor(s).

In accordance with another exemplary embodiment, with reference again to FIGS. **5** and **6**, a position sensing system can comprise a position sensor **522** and an encoder element, with position sensor **522** configured with stationary guide **514** to detect rotational position with the encoder element, e.g., an encoder strip, configured within or coupled to rotary device **512**. For example, with momentary reference again to FIG. **8*a*** position sensor **822**, such as a magnetic encoder, quadrature magnetic encoder, alternatively optical or other type of sensor device, may be attached to or configured within stationary guide **814** and positioned within or adjacent to slot **820**, while rotary device **812** can comprise a linearly encoded magnetic strip **824** or other like encoder device. In accordance with another exemplary embodiment, with reference again to FIG. **5**, position sensor **522** can be integrated inside or otherwise coupled to imaging probe **502** and interfaced to a control system. In such a case, an encoder strip is placed on the stationary guide **514** such that it can be detected by position sensor **522**.

In addition to a sensor and encoder strips, any other mechanisms for determining position of a first device with respect to a second device can be utilized. For example, the encoder devices and strips can be suitably combined with other encoders having one-degree of freedom, such as to provide a combined two-degree of freedom encoder device, a hemispherical-configured encoder or any other position encoder device. As another example, various limit switches can be configured along the displacement axis that can be suitably enabled by a latch or other enablement device configured with imaging probe **202**. In addition, both a limit switch configuration and a sensor/encoder strip configuration can be suitably implemented in accordance with various exemplary embodiments. Moreover, such components can be suitably configured inside and/or alongside imaging probe **202** and displacement guide assembly **212**. Still further, the positioning system, including the encoder and/or sensor components, can also be configured in combination with any other positioning device, such as a B-scan arm member or any other positioning devices and components.

In addition to being configured for controlled movement of probe **202** through use of a guide assembly **212**, position sensing system **214** can also be configured for determining position and/or direction of movement where the region of interest is under movement through use of a guide assembly. For example, in accordance with another exemplary embodiment, with reference to FIG. **9**A, a scanning, imaging, and/or therapy region of interest **906** may be achieved by moving objects **904** in a direction **920** past a probe **902** through a guide assembly **908** comprising a transport mechanism, such as a conveyor belt or other like arrangement. For example, objects **904** may be mice used in research, or any other desired objects. In this exemplary embodiment, probe **902** is acoustically coupled to object **904** through an acoustically compatible transport mechanism **908**. For example, guide assembly **908** comprising a conveyor or other transport mechanism can be made of a thin plastic-like material with low acoustic losses and suitable acoustic impedance, such as TPX plastic or others similar materials. Coupling media such as fluids like water or oils, and/or gels can be suitably utilized.

With reference to another exemplary embodiment as shown in FIG. **9**B, a single object or collections of objects **904** to be scanned or treated may also lie on and be acoustically coupled to a stationary or nearly stationary surface **918**, while probe **902** is swept in a direction **930** utilizing a guide assembly, such as guide assembly **212**, past and acoustically coupled to surface **918** to scan objects **904**. Surface **918** has the same favorable acoustic characteristics as a guide assembly **908** comprising a moving conveyor, namely an acoustically small thickness, low acoustic losses, and favorable acoustic impedance among others, such as an impedance similar to both objects **904** being scanned and/or treated as well as probe **902**. As a result, surface **918** provides efficient transfer of acoustic energy to and from scanned objects **904**.

In such rectilinear, rotational or translational configurations, position sensing system **214** can be interfaced to control system **204** via an appropriate communication interface, such as the Universal Serial Bus (USB) or any other available communication interface, such that the position of probe **202**, for example, the 2-D image frame position, and/or the direction of movement may be ascertained at any time while image frames are being collected. In addition, the speed of scanning can be determined by control system **204** through detection of position of probe **202** relative to the amount of scanning time, thus enabling a user to prevent under-sampling or under-treatment of volume of interest **206**.

The present invention has been described above with reference to various exemplary embodiments. However, those skilled in the art will recognize that changes and modifications may be made to the exemplary embodiments without departing from the scope of the present invention. For example, the various functional components and elements, as well as the components for carrying out the operational thereof, may be implemented in alternate ways depending upon the particular application or in consideration of any number of cost functions associated with the operation of the system. For example, the position encoder and sensor configurations can also be suitably configured for non-imaging applications, such as therapy, temperature monitoring, or any other tissue parameter effect or monitoring. In addition, the various components and devices can comprise numerous types of plastics, metals, woods, composites or other combination of materials thereof to provide the requisite structures or functions. These and other changes or modifications are intended to be included within the scope of the present invention, as set forth in the following claims.

The invention claimed is:

1. A method for facilitating controlled scanning of an imaging probe relative to a region of interest, said method comprising:

holding an imaging probe in a hand;

scanning a region of interest with said imaging probe in said hand;

restricting movement of said imaging probe through use of a guide assembly to rotation around an axis which is substantially perpendicular to a surface of the region of interest; and

determining position of said imaging probe within said guide assembly through use of a position sensing system to facilitate three-dimensional reconstruction of images by a control system, wherein restricting movement comprises coupling a guide member to said imaging probe.

2. The method according to claim **1**, wherein restricting movement comprises controlling movement in a rotational manner.

3. The method according to claim **1**, further comprising collecting a plurality of two-dimensional image planes to facilitate said three-dimensional reconstruction of images by a control system.

4. The method according to claim **1**, wherein said imaging probe comprises an ultrasound transducer configured with at least one of a single element, multiple element, or electronic array based transducer.

5. The method according to claim **1**, wherein said imaging probe is a combined imaging/therapy probe.

6. The method according to claim **5**, further comprising placing at least one therapeutic lesion with said combined imaging/therapy probe in said region of interest along said movement of said combined imaging/therapy probe through the use of the guide assembly.

7. The method according to claim **1**, further comprising monitoring at least one tissue parameter and reporting to said control system.

8. The method according to claim **1**, further comprising providing therapeutic treatment to said region of interest.

9. A method for facilitating controlled scanning of an imaging probe relative to a region of interest, said method comprising:

holding an imaging probe in a hand;

scanning a region of interest with said imaging probe in said hand;

restricting movement of said imaging probe within one-degree, of freedom through use of a guide assembly to rectilinear along a plane which is substantially parallel to a surface of the region of interest; and

determining position of said imaging probe within said guide assembly through use of a position sensing system to facilitate three-dimensional reconstruction of images by a control system.

10. The method according to claim **9**, further comprising collecting a plurality of two-dimensional image planes to facilitate said three-dimensional reconstruction of images by a control system.

11. The method according to claim **9**, further comprising coupling the guide member to said imaging probe.

12. The method according to claim **9**, wherein said imaging probe comprises an ultrasound transducer configured with at least one of a single element, multiple element, or electronic array based transducer.

13. The method according to claim **9**, wherein said imaging probe is a combined imaging/therapy probe.

14. The method according to claim **13**, further comprising placing at least one therapeutic lesion with said combined imaging/therapy probe in said region of interest along said movement of said probe through the use of the guide assembly.

15. The method according to claim **9**, further comprising monitoring at least one tissue parameter and reporting to said control system.

16. The method according to claim **9**, further comprising providing therapeutic treatment to said region of interest.

17. A method for facilitating controlled scanning of an imaging probe relative to a region of interest, said method comprising:

holding an imaging probe in a hand;

scanning a region of interest with said imaging probe in said hand;

restricting movement of said imaging probe within one-degree of freedom through use of a guide assembly to a prescribed path which is substantially parallel to a surface of the region of interest; and

determining position of said imaging probe within said guide assembly through use of a position sensing system to facilitate three-dimensional reconstruction of images by a control system.

18. The method according to claim **17**, further comprising collecting a plurality of two-dimensional image planes to facilitate said three-dimensional reconstruction of images by a control system.

19. The method according to claim **17**, further comprising coupling the guide member to said imaging probe.

20. The method according to claim **17**, wherein said imaging probe comprises an ultrasound transducer configured with at least one of a single element, multiple element, or electronic array based transducer.

21. The method according to claim **17**, wherein said imaging probe is a combined imaging/therapy probe.

22. The method according to claim **21**, further comprising placing at least one therapeutic lesion with said combined imaging/therapy probe in said region of interest along said movement of said probe through the use of the guide assembly.

23. The method according to claim **17**, further comprising monitoring at least one tissue parameter and reporting to said control system.

24. The method according to claim **17**, further comprising providing therapeutic treatment to said region of interest.

* * * * *